

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY)

2. REPORT TYPE
Technical Papers

3. DATES COVERED (From - To)

4. TITLE AND SUBTITLE

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory (AFMC)
AFRL/PRS
5 Pollux Drive
Edwards AFB CA 93524-7048

8. PERFORMING ORGANIZATION
REPORT

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory (AFMC)
AFRL/PRS
5 Pollux Drive
Edwards AFB CA 93524-7048

10. SPONSOR/MONITOR'S
ACRONYM(S)

11. SPONSOR/MONITOR'S
NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

MEMORANDUM FOR IN-HOUSE PUBLICATIONS

FROM: PROI (TI) (STINFO)

10 Jul 98

SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-TP-1998-160
Maj MacLachlan "AFRL Propulsion Directorate Briefing for Industry (PRS input)"
NAECON Briefing (Statement A)

20020823 048

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:

17. LIMITATION
OF ABSTRACT

18. NUMBER
OF PAGES

19a. NAME OF RESPONSIBLE
PERSON

a. REPORT

b. ABSTRACT

c. THIS PAGE

Unclassified

Unclassified

Unclassified

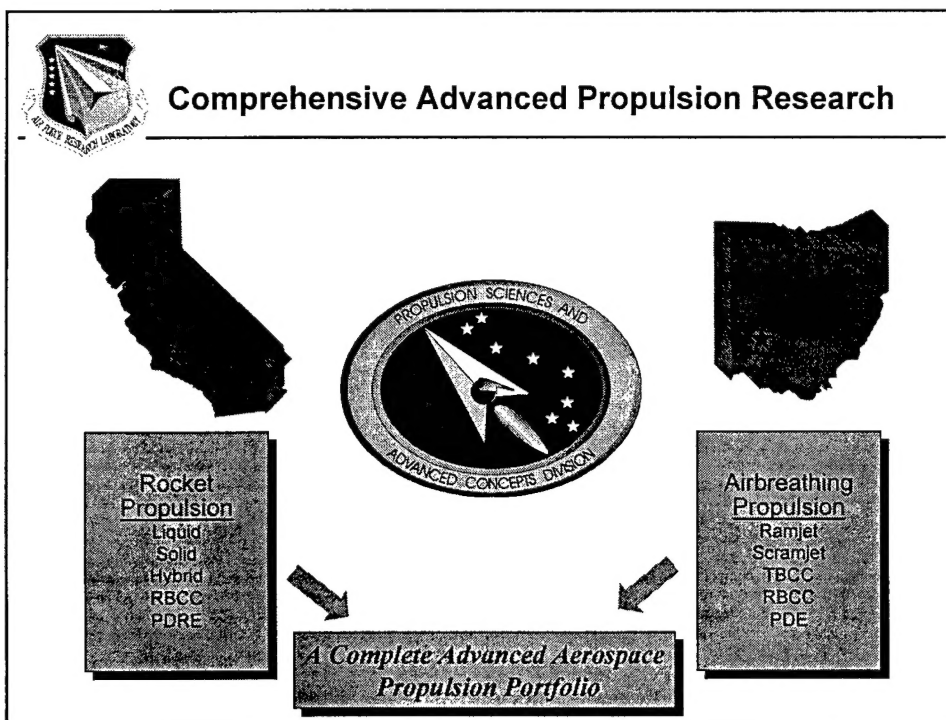
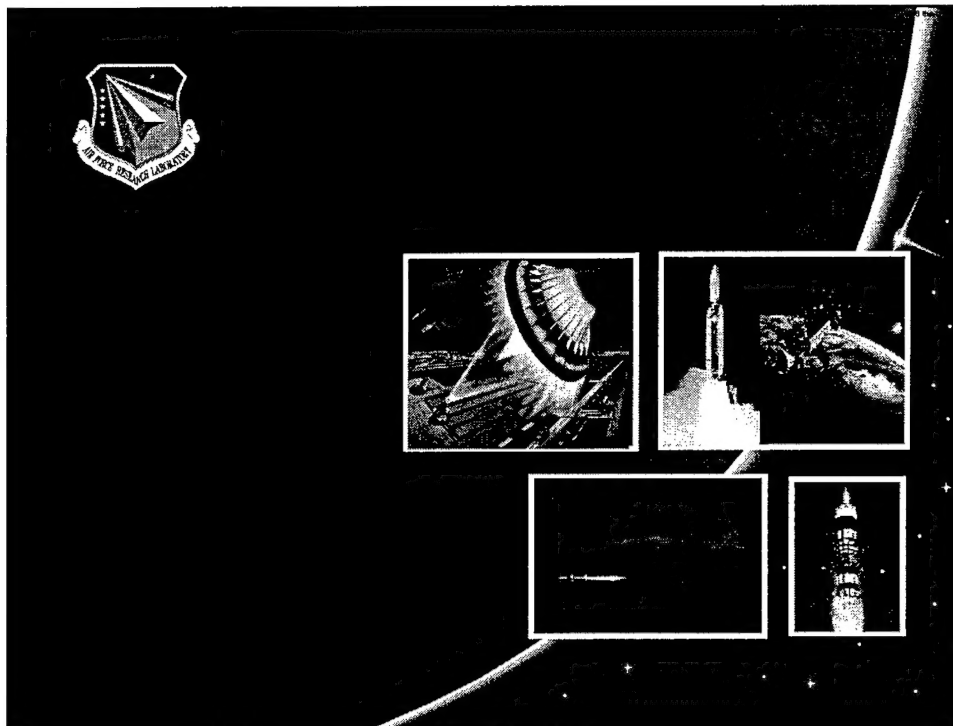
A

Leilani Richardson

19b. TELEPHONE NUMBER
(include area code)
(661) 275-5015

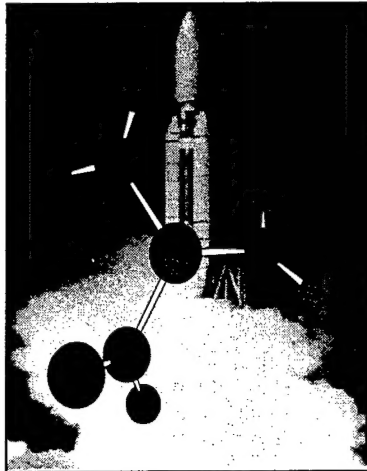
41 items enclosed

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18





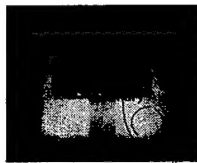
Technical Specialties



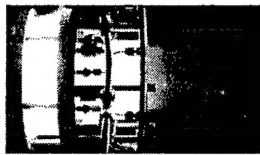
- Combustion
- Hypersonics
- Fuels and propellants
- Lubricants and mechanical systems
- Advanced components
- Advanced-concept system analysis
- Plume phenomenology



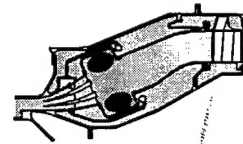
Trapped Vortex Combustor



6.1



6.2



6.3

ESTIMATED ADVANTAGES

- 35% Reduction in Cost
- 3.0% Reduction in Specific Fuel Consumption
- 25% Reduction in Combustor Weight
- 30% Increase in Altitude Relight
- Factor of 10 Reduction in Lean Blow Out Limit
- Factor of 20 Reduction in NOx

TECHNICAL CHALLENGES

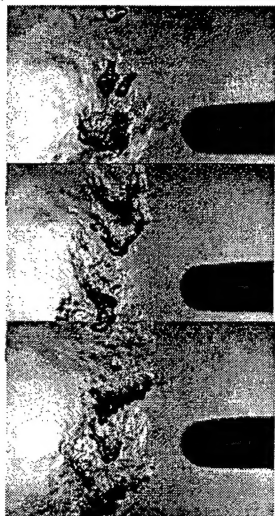
- High performance & acceptable pollutant emissions
- Flame stability
 - ★ Maintain flame stability at higher combustor flow velocities (>100ft / sec)
- Rapid fuel-air mixing
 - ★ Requires revolutionary mixing techniques

STATUS / PROGRESS

- Preliminary modeling & experiments conducted
 - ★ Excellent performance even at high velocities (>500ft / sec)
 - ★ NOx emissions far below current technology designs
- Significant potential as a major step forward
 - ★ General Electric Aircraft Engines to pursue development



Supercritical Combustion



Transcritical Oxygen Drops in Nitrogen

PROBLEM

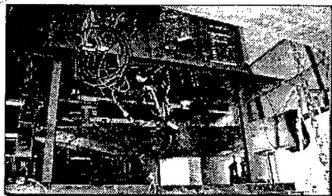
High-performance rocket and airbreathing engines operate in high-temperature/pressure "supercritical" fluid regime where surface tension vanishes, leading to unpredictable injection and combustion that must be corrected by trial and error

OBJECTIVE

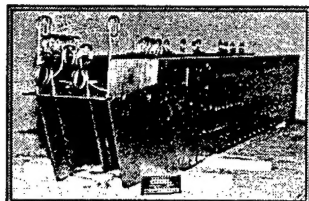
Determine the mechanisms that control the breakup, transport, mixing, and combustion of supercritical droplets, jets, and sprays, so future engines may be designed "right the first time"



HyTech Program



"Advanced cycle, dual mode ramjet/scramjet engines, and high temperature, lighter weight materials which allow for long range, long endurance, high altitude supercruise are the enabling technologies."

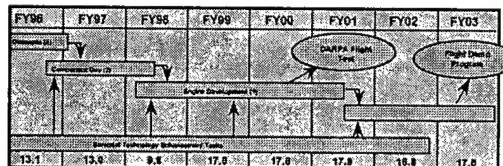


Develop/Demonstrate H/C SCRJ Technology

- Performance: Mach 4-8
- Durability: 12 Minute
- Maturity: TRL 6 (System in Relevant Environment)

Transition opportunity

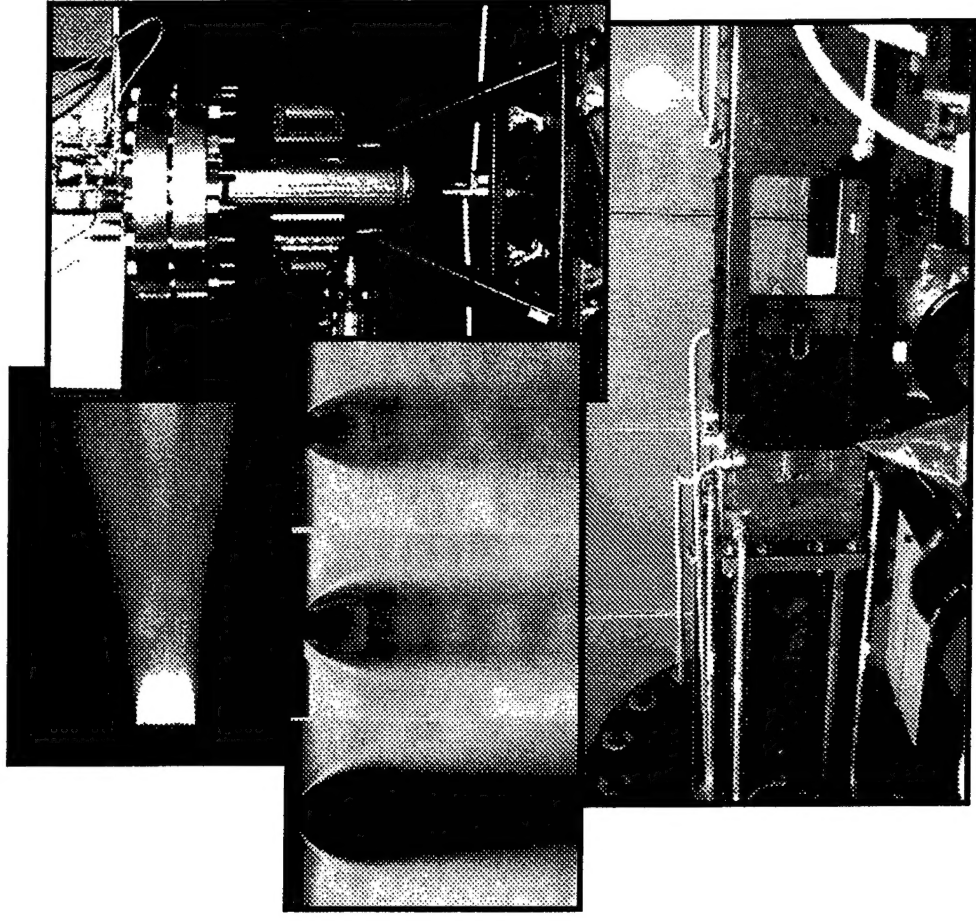
- DARPA Affordable Rapid Response Missile Demo (Heavy, fixed Mach)
- AFRL/MN Time Critical Target Technology
- Demo Program (Full function engine)
- Fast Reaction Stand-off Weapon Pgm





Ram/Scramjet Research

- Available Facilities
 - Water-Cooled Combustor
 - Fuel Injection Tunnel
 - Direct-Connect Thrust Stand
 - Ducted Rocket
 - Scramjet
 - Supercritical Injection Chamber
- Supersonic Combustor under Development
 - Currently configured for $M = 1.8$ crossflow
 - Ethylene fueled vitiator limited to 150 psia
 - Nominal flowpath cross section dimensions: 1.5" x 4.0"
 - Well instrumented, accessible for optical diagnostics





Fuels and Lubrication Objectives

- **HIGHER HEAT SINK FUELS**
 - Improve Aircraft Thermal Management
 - Reduce Fuel System/Engine Fouling
 - Reduce O&M Costs
- **IMPROVED COMBUSTION**
 - Reduce Development Time and Risk (Cost)
 - Expand Engine Performance Envelope
 - Reduce Atmospheric Pollution
- **IMPROVED LUBRICATION SYSTEMS**
 - Longer Life, Higher Temperature Lubes
 - Reduce Weight/Life Cycle Cost
 - Increase Speed/Temperature Capability
 - Corrosion Resistant Bearings



SYSTEM PAYOFF

- Improved Reliability
- Lower Life Cycle Cost
- Improved Performance
- Reduced Env'l Impact



Vapor Phase Lubrication

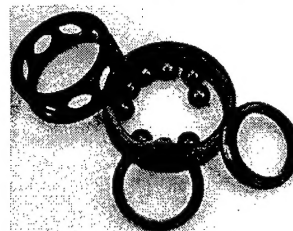
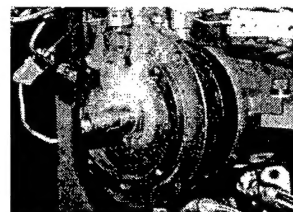
Demonstrated, for First Time, Sustained Operation at Gas Turbine Conditions w/o Liquid Lubrication

KEY TECHNOLOGIES:

- Deposition & Condensate Lubricant (TBPP)
- Carbon-Carbon Composite Cage
- Solid Lubricant Coating
- Oil Mist Delivery
- Computer Modeling and Design

PAYOFFS (Limited Life Engine):

- 90% Reduction in Lube System Weight
- 15% Reduction in Engine Cost
- Higher Temperature Capability (204 to 650°C)



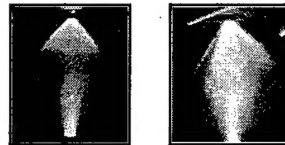
Auxiliary Support for Magnetic Bearings!



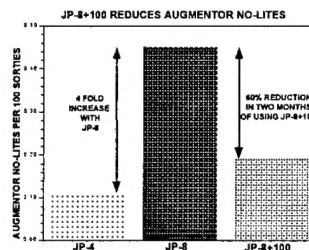
“JP-8+100” Improved Thermal Stability Fuel

WHAT IS JP-8+100?

- JP-8 With Thermal Stability Additive Package
 - Antioxidant
 - Metal Deactivator
 - Detergent
 - Dispersant
 - Added at 100 - 300 ppm
- +100°F Increase in Stability
 - Bulk Temp: 325°F to 425°F
 - Wetted Wall Temp: 400°F to 500°F
- Cost Goal: \$0.001/gallon
 - \$1.50 to Fill Up F-15
- Specification By FY99
 - Worldwide Use



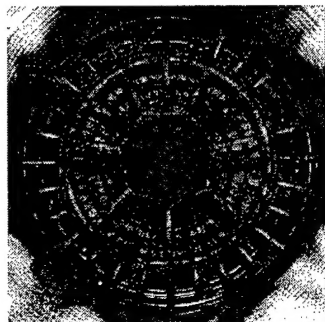
- Coking/Fouling/Sooting Distorts Spray
- Causes Engine Hot Streaks and Damage
- Contributes to High Cycle Fatigue



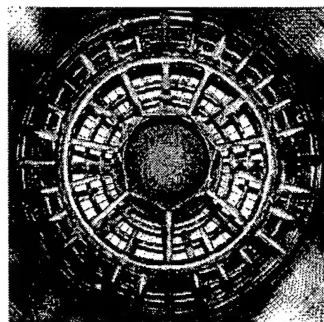
JP-8+100 Demonstration

Kingsley Field, OR (F16/F100-200)

200+ Hours on JP-8

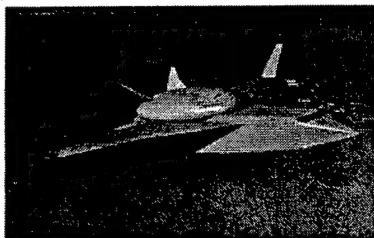


200+ Hours on JP-8
then
56 Hours on JP-8+100





Advanced Monopropellants



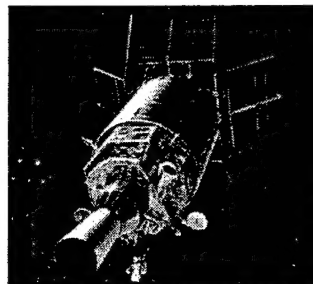
Description:

Monopropellants for high performance, simple, easy to use, highly maneuverable military space vehicle

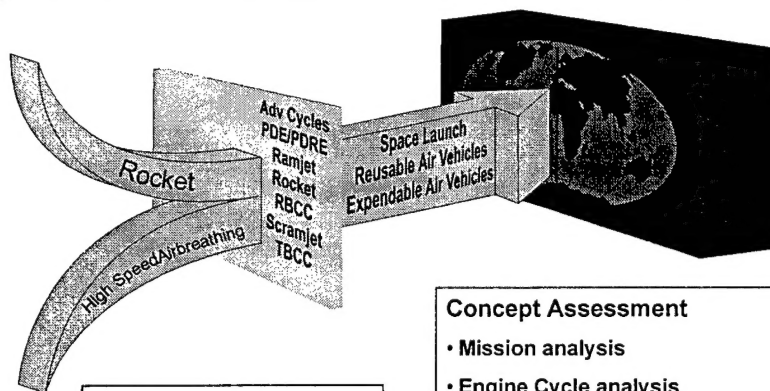
- Single propellant for entire vehicle
- Eliminates one pumping system
- Eliminates cryogenic storage/use
- Enables airplane-like operations

Payoff:

- Simple propulsion system
- On-demand launch
- Any orbit or inclination virtually anywhere on earth
- Take off anywhere, land anywhere
- Easy to load
- Non-toxic replacement for hydrazine
- Double satellite on-orbit lifetime



Full-Spectrum Research and Integrated Vehicle/Propulsion Assessments



Enabling Technologies

- Lightweight materials
- Advanced propellants
- Injection & combustion

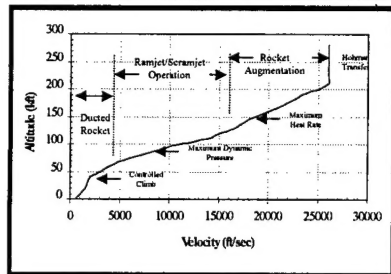
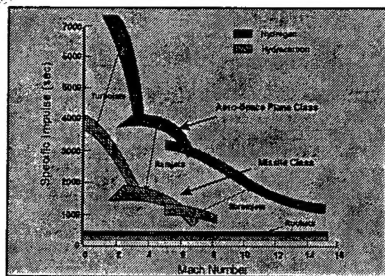
Concept Assessment

- Mission analysis
- Engine Cycle analysis
- Tool development & modification

One-stop "global" propulsion research & analysis

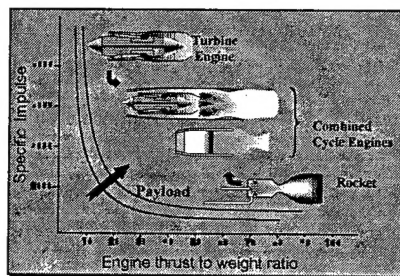


Integrated Propulsion for Space



Bridge Air & Space

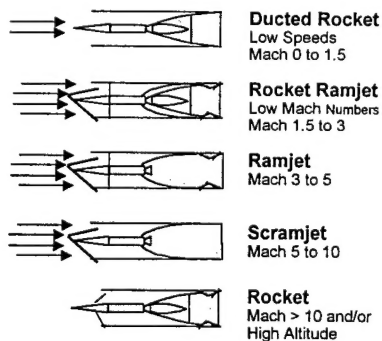
- Move to aircraft-like operations
- Global reach in 2 hours or less
- Bootstrap to spacelift



Rocket-Based Combined Cycle

Payoff

- Enables space launch systems that can deliver payloads for 10% of current costs
- Enables a broad range of military transatmospheric applications
 - Global Reach
 - Reconnaissance
 - Force Application
 - Space Control



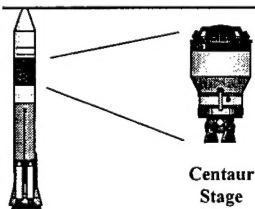


Space Lift Concepts

- RBCC TSTO: HyperSoar
- LACE TSTO: Space Access
- Launch Assist: Pioneer RocketPlane, RASV, KST Astroliner, Maglev, X-34
 - Air Launch
 - Rail Launch
- Rocket Recoverable TSTO: Kistler K-1
- MSP Pop-Up: RLV / X-33 Derived
- Rocket SSTO: RLV
- RBCC SSTO: NASP, Vision, Trailblazer



Performance Improvements Due To:



Atlas IIAS

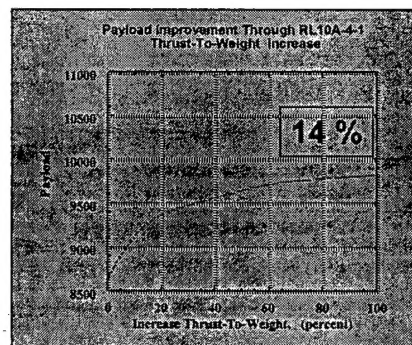
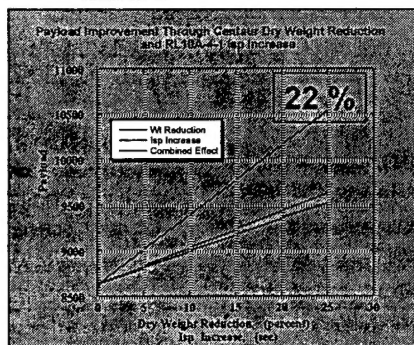
Centaur Stage

- 1) Weight Reduction
- 2) Increased Engine Specific Impulse
- 3) Increased Engine Thrust-To-Weight

Baseline Payload
(GTO Mission)
8625 lb_m

$$\Delta V = g_0 I_{sp} \ln \left[\frac{m_0}{m_f} \right]$$

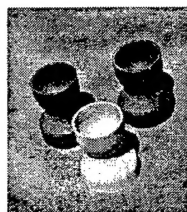
m_0 = initial stage mass, lbm
 m_f = final stage mass
 I_{sp} = engine specific impulse
 g_0 = gravitational constant





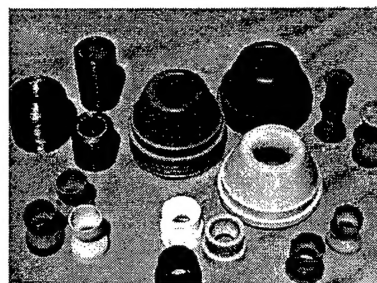
Inverse-Processed Nozzles/Throats/Chambers

Innovation Enables High-Performance Designs



Production Steps

- 1) Spray/Cast/Machine Liner
- 2) Fiber Wrap/Braid
- 3) Densify C-C

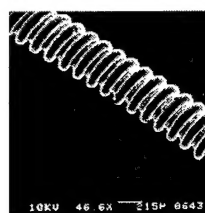


Payoff:

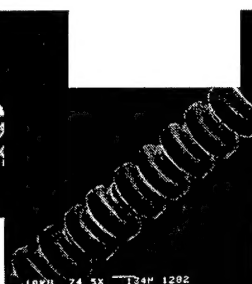
- Liquids: 4000 °F radiation cooled, oxidation resistant nozzles increase booster thrust-to-weight 15% (RL-10)
- Spacecraft: Long-life (>10 hr) rhenium-lined C-C thrusters at 10% the cost
- Tactical: Erosionless throat increases AMRAAM delivered Isp by 6 sec



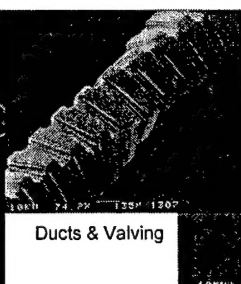
Microdevice Fabrication and Micropropulsion



Heat Exchangers



Pressure and Temperature Sensors



Ducts & Valving



Microthrusters

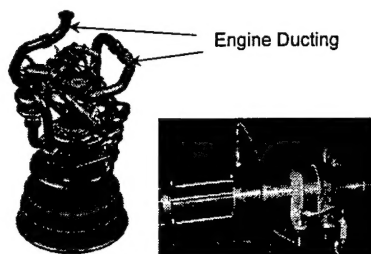
- Revolutionary method can make any 3-D micron scale shape from any material--1st reliable 3-D manufacturing method
- Will enable ultra-small satellites for sensing & exploration missions
- Thousands of micro-sensors can be imbedded in propulsion system components--enabling huge increases in system reliability



Plastics for Rockets

Crucial to Reducing Weight and Cost

Liquid Rocket Engines

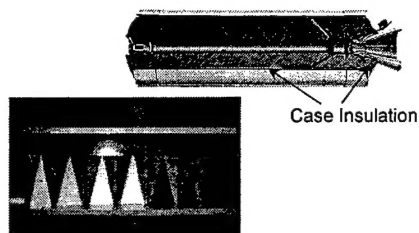


Polymer Tube/Case Hot Gas Burst Tester

Plastic Engine Ducting (SSME)

- 80% duct weight decrease
- 15% upper stage thrust-to-weight increase

Solid Rocket Motors



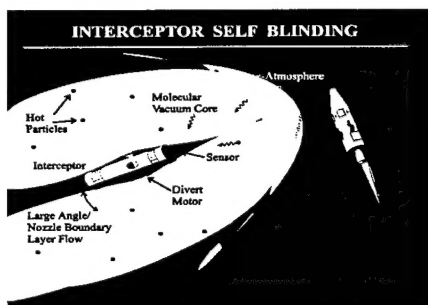
Char Motor Polymer Insulation Samples

50% Lower Erosion Insulation

- Cuts Booster Insulation weight 44%
- Increases Booster Payload 7.4%



Missile Plume Signatures



Payoff

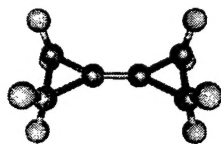
- Improved Discrimination with Countermeasures
- Reliable - All Weather Detection & Tracking
- Robust Boost Phase Intercept Capability

Goals

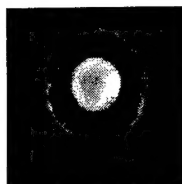
- Fulfill Identified TMD and NMD System Requirements
- Identify, and Resolve Plume Technology Deficiencies
- Transition the Use of Plume Technology From Developers to Users
- Provide Timely System Support and Consultation to BMDO/AF Programs



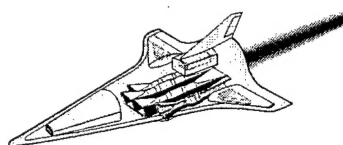
Revolutionary Propulsion Technology



High energy-density matter (HEDM)



Plasma-assisted drag reduction and combustion enhancement (Ajax)



Low-cost pulsed-detonation propulsion (PDP)



Laser propulsion



Micropropulsion



Propulsion Sciences & Advanced Concepts Division

Edwards AFB CA

Aerophysics
Jay Levine
805-275-6179

Propulsion Material Applications
Maj Mike MacLachlan
805-275-5230

Propellants
Dr. Pat Carrick
805-275-5883

Dr. Steve Rodgers 805-275-5230
Dr. Phil Kessel 805-275-5591
Leo Harootyan 937-255-2394
Parker Buckley 937-255-7266

Applications & Assessment
Steve Mozes 937-255-9991
Dr. Ray Moszee 805-275-5534

Wright-Patterson AFB OH

Lubrication
Maj Walt Lauderdale
937-255-5568

Combustion
Charlotte Eigel
937-255-6814

Fuels
Bill Harrison
937-255-6601

High Speed Systems
Maj Kenneth Philippart
937-255-5221